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EDITORIAL

Dear IIOE-2 member,

Greetings from the Indian Ocean region!

We feel very happy to put this latest issue of Indian Ocean-Bubble in your hands. As always, the issue features a wide variety of interesting articles dealing with the Indian Ocean Science. In addition, this issue comes to you when we are in the process of mapping the future of Indian Ocean science under IIOE-2 beyond 2025.

Immediate focus is on the amalgamation of our efforts into the UN Ocean Decade. Going with that theme, this issue also features the first ever in-person regional ocean decade conference hosted, as a matter of proud for all of us, nowhere else but in the IOR. Another aspect is the endorsed ocean decade action being pursued by the young guns of IIOE-2 (yes, the ECSN). This issue brings report of the DECCaD-IO trainings being spearheaded by the network.

We eagerly look forward to your feedback to this issue as well as submissions for the next one.

On behalf of the IIOE-2 PO team,
N. Kiran Kumar, Nimit Kumar
and Aneesh Lotliker

IN THIS ISSUE

Ecosystem and Biodiversity

WIO-Benth - mapping benthic habitats and faunal communities in the WIO

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The impressive marine biodiversity of the western Indian Ocean (WIO) is particularly well known from critical habitats in coastal and shelf waters, such as coral reefs, seagrass meadows and mangrove forests. In contrast, unconsolidated soft sediment habitats and their communities are less well known; although they have been sampled over the years, there hasn't been a consolidated attempt to describe and map them at the regional scale. The lack of knowledge of this habitat in the region, particularly in offshore waters, is hampering marine spatial planning, and decision makers are not equipped to assess the implications of trade-offs between extraction of non-renewable resources, harvesting of renewable resources, and conservation, for example. This was the rationale for the WIO-Benth project, which set out to describe seabed habitats and their faunal communities in Kenya, Tanzania, Mozambique, and South Africa. The project posed these research questions:

1. What seabed types comprise the shelf and upper slope (to 1000m) of the WIO?

2. What benthic communities are associated with these areas?

3. What are the biotopes in these areas?

In answering these questions, the project intended that existing data be analysed to develop the first regional-scale marine biotopes of the shelf and upper slope, to assist with marine spatial planning in the western part of the WIO.

The project was funded by the MASMA programme of the Western Indian Ocean Marine Science Association (WIOMSA), with support from the EAF Nansen Programme, and was led by the Oceanographic Research Institute (ORI) in South Africa, with collaborating institutes from the three mainland East African states and Madagascar (particularly KMFRI, TAFIRI, InOM and MPEB). Valuable support was also provided by universities (KwaZulu-Natal, Nelson Mandela, Stellenbosch, Cape Town, Colorado) and the Institute for Marine Research in Norway. Seabed habitats were determined from a combination of georeferenced and digitized navigational chart data, survey acoustic soundings, as well as from the global dbSEABED mapping initiative. Faunal information was obtained from a variety of bottom trawl surveys and observers on commercial trawlers, and were compiled and validated before analysis, a process which took considerable time.

A seabed classification system for the WIO was produced, with features such as canyons, ridges, submerged dunes and paleo shorelines, and attributes related to sediment types such as sand, mud, and gravel. Project geologists interpreted the attributes and features in conjunction with the bathymetry to spatially delineate seabed habitats according to the developed classification scheme, including the derivation of seabed aspect and slope, and position and distinctness of the shelf break. To further characterize seabed habitats, physico-chemical/hydrographic parameters were considered. Several predictors of community faunal distribution patterns were identified for use at the regional scale, including depth, bottom temperature and salinity, seabed substrate type, grain size, sorting, seabed slope and rugosity, bottom current strength, mean bottom temperature and oxygen, turbidity, aspect, slope, and latitude.

Based on information from charts, the majority of the WIO shelf and upper slope in the project's Area of Interest (ca. 360000 km^2) was found to be unconsolidated sediments, with sand comprising 40%, rock 25% and mud 14%, and with 16% being a mixed category of several sediment types. The remainder comprised a combination of coral, shell, gravel and algae. From the ca. 1700 bottom trawls, a total of 1750 taxa were finally recognized after validation; since the focus was on the seabed, further analyses were confined to the ca. 800 benthic taxa only. The most commonly occurring taxa were Saurida (lizardfish), Chlorophthalmus (green eyes), Chaunax (coffin fish) and Peristedion (armoured gurnards; Fig. 1). Multivariate analyses showed temperature, depth, and latitude to be the most influential

Fig. 1: A bottom trawl catch from the upper continental slope in the WIO

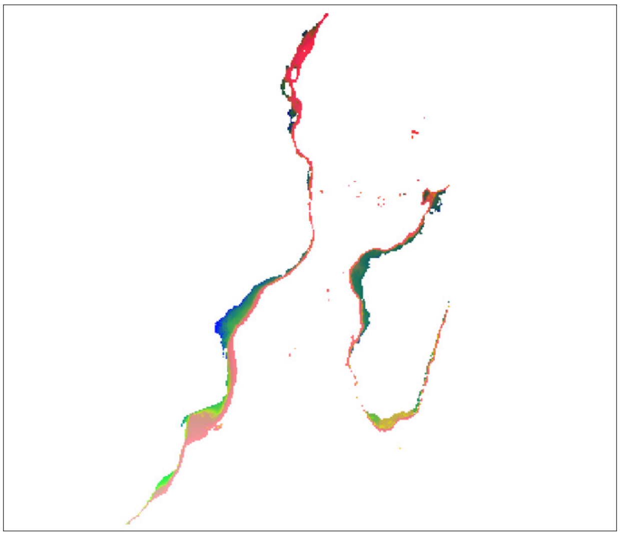

Fig. 2: Preliminary predicted benthic faunal compositional similarity between sites in the WIO-Benth Area of Interest, produced by generalized dissimilarity modelling; the strongest differences in colour indicate greatest predicted differences in species composition.

factors in distinguishing between faunal community clusters. Preliminary generalized dissimilarity modelling of communities and environmental predictors also emphasized the marked differences between shelf and slope fauna and suggested a north-south distinction in community composition (Fig. 2).

Biotopes were obtained by relating environmental habitat attributes at the ca. 1700 trawl localities with the benthic fauna found there; initially, >1500 unique habitats (based on combinations of 14 habitat attributes) were identified across the region – these were subsequently rationalized using Analysis of Similarity to produce around 200 unique habitat topes based on the six most influential attributes (salinity, bathymetry, distance from shore, latitude, turbidity, sediment type), which were then linked to their associated fauna to produce the biotopes. The biotope plot showed spatially distinct groupings, particularly off Mozambique where central and southern areas are highly distinguished, but with some similarities at a smaller scale with eastern South Africa, while Tanzanian biotopes are quite contrasted (Fig. 3).

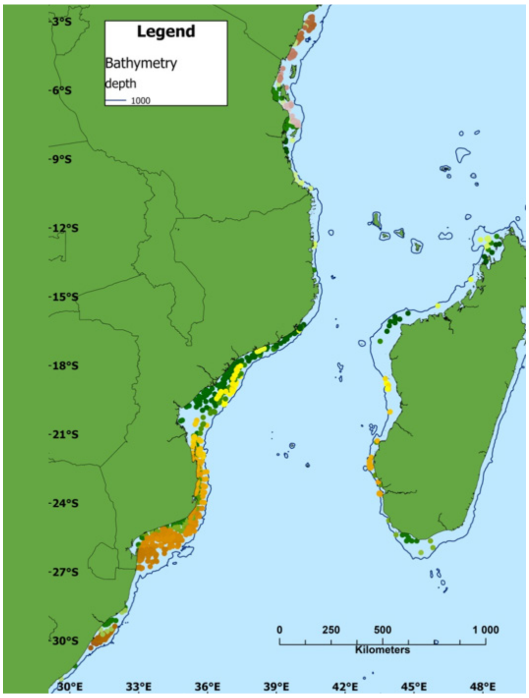

Fig. 3: Map of ca. 200 biotopes based on habitats and benthic fauna at trawled localities in the WIO-Benth Area of Interest. Colours are ramped so not all biotopes are distinguishable at this scale.

This is the first attempt to map seabed habitats in the WIO at this scale and must be treated as such. Further, the seabed habitat map is a model based on available data; while the amount of data assimilated for the WIO region appears impressive, the area is huge, and supplementing the seabed habitat data via new surveys, or from alternative sources, should be a priority. Sediment grab data can be used to validate the predicted seabed types; we vigorously pursued records of grabs from the region, but there have been few such surveys in the WIO. Use of video footage from surveys can also be used to validate predicted habitats, but was beyond the scope of this project; also, such surveys tend to be confined to reef habitats, whereas our focus was largely on unconsolidated habitats.

Numerous scientific publications will be produced from the project, as well as an atlas for the WIO; the intention is to ultimately house the information with the Nairobi Convention for future use, and will improve the capabilities of marine spatial planners in the region.

Bay of Bengal Monsoons: Primary production and Algal cultures

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Monsoons

Known as the largest bay on the planet, the Bay of Bengal (BoB), of the northeastern Indian Ocean, receives annually ~1.5 x 1012 m^{-3} river water and 2000 x 106 tons sediment (Mohanty et al. 2008). Within the BoB, monsoon forcing produces distinctive, seasonal circulation patterns. During winter monsoon, (Northeast Monsoon, NEM Nov-Feb) winds blow from the northeast and large volumes of freshwater are driven along the east coast equatorward, resulting in the East India Coastal Current (EICC) (Rainville et al. 2022). During the warmest months (June -September) winds are reversed (Southwest Monsoon, WM), and the southwesterly winds force high-salinity waters from the Indian Ocean and the Arabian Sea into the BoB resulting in a Summer Monsoon Current (SMC). During this period the BoB is rendered oceanic and also experiences coastal upwelling south of Sri Lanka and on the east coast of India as well (Vinayachandran et al. 2004, Rao et al. 2006). Thus, these reversing monsoons and the upwelling of nutrient rich bottom water act as forcing functions on the BoB phytoplankton ecology. Because of these unique features, the BoB is regarded as nature's experiment for biological oceanographers.

There have been several seasonal planktological studies along the east coast (Hoogly estuary, Chilka lake, Puri, Visakhapatnam, Pichavaram, Kalpakkam, Muthupettai, Porto Novo, Lake Pullicat, Palk Bay, and Sri Lanka). Sampling was limited to an opportunistic basis. A general feature is a bimodal peak distribution with a major peak during SWM and a minor one coinciding with the NEM. The qualitative and quantitative constituents and production characteristics of the major bloom during SWM are marine and contrasts the more estuarine during the NEM. Of the ~300 coastal phytoplankton species, 20 occur in the BoB round the year, >60 during the SW monsoon of which 30 bloom. While 10 species are restricted to the SWM, only 6 are limited to NEM; common to both blooms were Bacteriastrum delicatulum, Thalassiothrix frauenfeldii, Proboscia alata (Rhizosolenia alata), and Chaetoceros coarctatus. Stephanopyxis palmeriana, Streptotheca indica, and Planktoniella sol were observed mostly in upwelling waters (Subba Rao, 1976).

Heavy blooms of phytoplankton were reported mostly during pre-monsoon season (Padmakumar 2012, D'Silva et al. 2012, Oyeku and Mandal 2021) and are attributed to the enrichment caused by riverine discharge or upwelling of nutrient rich subsurface waters. There were 154 marine microalgal blooms (MMBs) during 1908 to 2017, constituted by 74 genera and 7 classes of algae. They suggested that increasing Sea Surface Temperature and anthropogenic influences around the Indian peninsula could increase the occurrences of marine microalgal blooms and harmful algal blooms (HABs).

Primary Production

Observations of Prasannakumar et al. (2002) during a summer cruise in the offshore waters of BoB along 88°E from 7°N to 20°N (6 July to 2 August, 2001) showed surface chlorophyll a (chl a) increased from 0.06 mg m^{-3} in the south to 0.28 mg m^{-3} in the north and integrated biomass 9-11 mg m^{-2}. Integrated primary production in the Bay of

Bengal ranged between 89 to 221 mg C m^{-2} d^{-1}. Subsurface chl a (SCM) in the BoB varied between 20 and 60m and ranged between 0.14 and 0.28 mg m^{-3}. Based on this they stated that integrated biomass for the Arabian Sea (AS) is 3-5 times higher and the primary production 8 times higher than that of the BOB. Column integrated chl a and primary production during winter in the BoB were 4.6 and 6.4 times lower respectively than in the AS (Jyothibabu et al. 2004). These authors attributed the low biological production in the BoB to depletion of nitrate although silicate levels were high.

Table 1. Summary of ranges of phytoplankton biomass and primary production in India Seas based on Löscher, 2021, Prasannakumar et al. 2010, and Matondkar et al. 2006 and the references cited therein.

Region	Season	Chl. a. mg m^{-2}	Primary Prod. mgC m^{-2} d^{-1}	References
Spring Inter-Monsoon	BoB	23.6 – 34.6	411-920	Sarma et al. 2019
			182-1261	Anand et al. 2017
			250-469	Gauns et al. 2005
Mar. - May		11.2- 42.9	250.0-470.0	Prasanna Kumar et al. 2007
	NE - AS	14.0 - 62.4	436.58-2711.61	Prabhu Matondkar et al. 2006
			60.0-240.0	Radhakrishna 1978
			165.5-516	Matondkar et al. 2006
Summer Monsoon June-Aug.	BoB	11.2 - 42.9	20.0-510.0	Prasanna Kumar et al. 2007
		97-165	300.0-550.0	Gomes et al. 2000
		1.28- 50	180-2200	Bhattathiri et al. 1980
		1.84-5.2	89.4-220.6	Muralidharan et al.
			288-1044	Saxena et al. 2020
		9.0-18.7	40.0-500.0	Madhupratap et al. 2001
		2.1-23.2	140.0-5590.0	Deevassy et al. 1983
Fall Inter- Monsoon Sept. – Oct.	BoB	1.1-50.5	120.0-341.0	Bhattathiri 1978
			284-364	Kumar et al. 2010
Winter Monsoon Nov. – Feb.	BoB	11.3-13	230.0-350.0	Madhu et al. 2006
			87-187	Balachandran et al. 2008
			115-187	Jyothibabu et al. 2004
			203-430	Singh et al. 2015
			253-566	Gauns et al. 2005
			184-512.85	Kumar et al. 2004
	NE - AS	14.00-62.84	21.14-7343.33	Matondkar et al. 2006

Column integrated phytoplankton biomass and primary production for all 4 seasons in the BoB and for spring and winter for the NE Arabian Sea (NE-AS Table 1 and the references therein) show existence of large variations in the BoB i.e. 1.1 to 165 mg m^{-2} chl a and the primary production between 40-5590 mgC m^{-2} d^{-1} compared to 4 -7343.3 mgC m^{-2} d^{-1} in the Arabian Sea. This suggests the existence of a potential for hot spots of biomass and production in both the BoB and AS during all seasons, despite spatial and temporal variations in sampling. It is possible that integrated annual seasonal data for a locality yields a better basis for evaluation of potential production. Some of the nearshore regions or estuarine brackish waters may have higher biomass and production, particularly during the blooms. Columnar primary production (mgC m^{-2} d^{-1}) is high; in Cochin estuarine backwaters (Qasim et al. 1969) ranged between 1210 -5860 and 14.6-1459 in Goa estuary (Krishnakumari et al. 2002). It should be noted that carbon assimilation ratios (mgC mg Chl a h^{-1}) under optimal conditions provide reliable indices of the efficiency of photosynthetic functioning of a body of water. Such a comparison is easier done with exceptional monospecific algal blooms which are rare or utilizing algal cultures.

Based on field data, several hypotheses centered around nutrients were prompted to account for the low plankton biomass and production in the BoB. Of interest, Sarma et al. (2019) reported primary production in the upper 25 m of water column of BoB comparable to that in the Arabian Sea and associated it with the DON and DOP that constitute up to 70-99% to the total dissolved nutrients. Another hypothesis suggests several cyclonic (CE) and anticyclonic (ACE) eddies in the BoB contain different proportion of nutrients due to divergence and may positively impact phytoplankton composition (Sarma et al. 2020). Another related hypothesis priming primary production is the role of episodic events, cyclones (Maneesha et al. 2011), mesoscale eddies (Vinayachandran and Mathew, 2003) that can erode the stratification of the upper layer and facilitate pumping up nutrient rich deep water. Severe limitation of phosphate and nitrate in the northern BoB (Sarma et al. 2020) is another hypothesis to account for low phytoplankton. However, historical data (1908-2017) showed high nutrients (NO_3-N, PO_4-P, and SiO_4-Si) and low salinity triggered blooms of prymnesiophyceae, raphidophyceae, bacillariophyceae and dinophyceae in the waters around Indian peninsula (Oyeku and Mandal, 2021). 'Oligotrophy' in the BoB is attributed to thermohaline stratification (throughout the year), low solar radiation and turbidity (Jyothibabu et al. 2018), and severe light limitation in the northern BoB due to riverine discharges (Prasannakumar et al.2010). Deficit monsoon (DM) and normal monsoon (NM) are implicated in variation in column biological production in the BoB (Jayalakshmi et al. 2022). Warm basin with relatively high chl a and primary production characterize the DM. It is hypothesized that increased light availability (less cloud cover) extended euphotic depth, and low mesozooplankton grazing may have contributed to high production in the DM. Thus, these hypotheses based on field data suggest the crucial role of macro and trace nutrients, and availability of photosynthetic active radiation (PAR) play in regulating phytoplankton in the BoB. However, precise photosynthesis - irradiance studies utilizing algal cultures would be necessary to evaluate whether solar radiation in fact is limiting photosynthetic functioning in this tropical bay.

Phytoplankton and cultures

To understand the structure and functioning of phytoplankton, the starting point is to utilize laboratory cultures, established from NEM and SWM, as analogues of natural blooms for investigations on their potential for photosynthetic production in a salinity gradient, nutrient regimes, and photosynthetic active radiation. They also provide data on their response and recovery to continual influx of several chemicals from anthropogenic perturbations that probably break down any seasonal phytoplankton cycle.

Table 2. Microalgal culture collection centers

Center	Country	Address	Strains cultured
CCMP	USA	National Center for Marine Algae and Microbiotancma@bigelow.org	2100
UTEX	USA	The UTEX Culture Collection of Algae at the University of Texas at Austin www.bio.utexas.edu/research/utex	3000
UTCC	Canada	Canadian Phycological Culture Centre www.botany.utoronto.ca/utcc	258
CCAP	Scotland	The Culture Collection of Algae and Protozoa of The Scottish Association for Marine Science www.ife.ac.uk/ccap	3000
RCC	France	Roscoff Culture Collectonvaulot@sb-roscoff.fr	5000
SAG	Germany	The Culture Collection of Algae at The Gottingen University www.epsag.uni-goettingen.de/html/sag.html	2300
NIVA CCA	Norway	Norwegian Culture Collection of Algae	2000
CSIRO NACC	Australia	The Australian National Algae Supply Service www.csiro.au	3000
CICCM	New Zealand	The Cawthron Institute Culture Collection of Micro-algae https://www. cawthron .org.nz	450
NIES	Japan	The National Institute for Environmental Studies Collection www.nies. go.jp/biology/mcc/home.htm	935
CCVIEO	Spain	https://vgohab.es/coleccion-de-cultivos	400
CODIMAR	Mexico	https://www.cibnor.gob.mx/investigacion/colecciones-biologicas/codimar	149

IOUSP	Brazil	Marine Microalgae Culture Collection secrdob@netuno.io.usp.br	Several
CCTCC	China	Chinese Centre for Type Cultures Collections	1000
IPPAS	Russia	Culture Collection (Institute of Plant Physiology, Russian Academy of Sciences)	430

Although algal culture studies were initiated almost 120 years back in the west (Table 2), situation in India continues to be inadequate. The National Institute of Technology, Tiruchirappalli utilizing freshwater algae Chlorella, Spirulina and Scenedesmus investigates environmental remediation and wastewater treatment. At the Central Food Technological Research Institute India, Mysore, India, the team of Dr. Sarada Ravi utilizes cultures of Spirulina platensis, Desmodesmus sp. Porphyridium purpureum and Dunaliella salina, Chlorella vulgaris for investigations on bioactive compounds.

Experimental results on Biddulphia and Ceratium (Qasim 1973) are of interest; these tropical marine algae seemed to adapt and regulate their peak photosynthetic production during the monsoon months when nutrients in the nearshore waters are high and salinity low. Sivagurulingam et al. (2022) utilized mass cultures of Nannochloropsis salina, Dunaliella salina, Chaetoceros calcitrans, Tetraselmis chuii and Euglena sanguinea to investigate biodiesel production. Keerthi (2017) cultured 60 strains of the halophile Dunaliella including 16 carotogenic and several

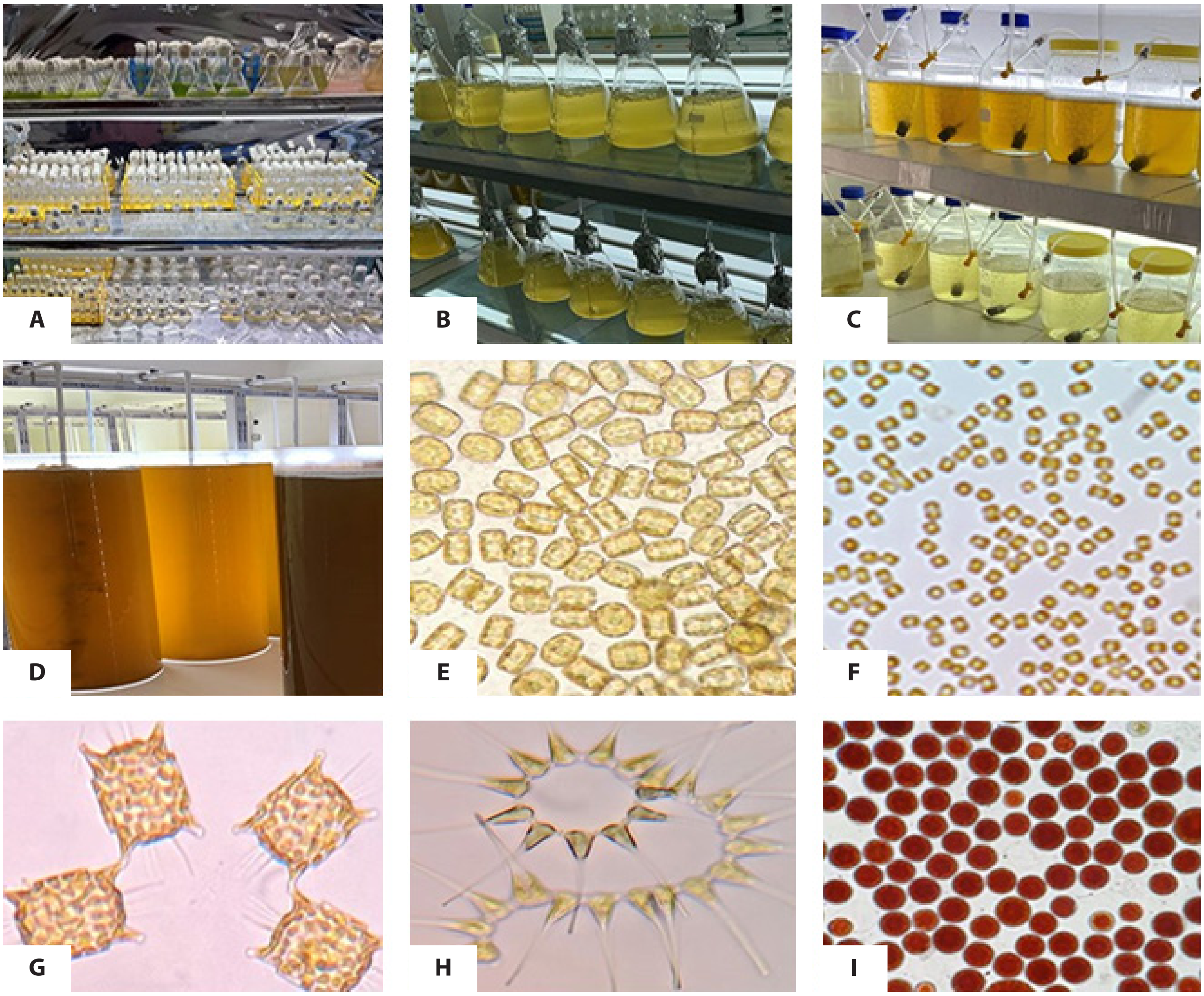

Plate 1. Isolation and scaling up of indoor algal cultures A, B, C, D and outdoor mass cultures, E, F. species of Thalassiosira, G- Odontella , H- Asterionella and I- Carotogenic Dunaliella.

diatoms from the BoB (Plate 1. A to I). Results yielded high levels of cellular lipids and carotenoids. Also, he optimized culture media and investigates growth of axenic cultures of ~70 microalgal isolates belonging to 20 species of green algae, diatoms, Prymnesiophytes, nanoplankters and pico plankters under a variety of environmental variables (Figs. 2-6) and showed that cultures of the diatoms Cylindrotheca and in Odontella aurita are a rich source of polyunsaturated fatty acids (Keerthi et al. 2012, 2013).

More microalgae native to the Indian Seas need be cultured and studied. Andersen's comprehensive reference work (2004) provided information on media preparation, isolation and purification techniques, mass culturing, and growth measurements, and reviewed applications of algal culture techniques for environmental investigations. Several aspects including algal cultures, autecology of blooms, photosynthesis -irradiance relationships, nutritional value of microalgae, biotechnological applications, prospects for para transgenic applications, and statistical models for prediction of phycotoxins are detailed by Subba Rao (2006, 2009, 2018 and 2020).

Marine microalgal biotechnology aims at the application of scientific and engineering principles to the processing of marine microalgae. Projections for Global Marine Biotechnology to reach US $~7.3 billion y-1; India's share is $100 million. The marine biotechnology in India is young and should explore the enormous potential from marine biotechnology, particularly to cultivate microalgae for the production of bio-energy, pharmaceuticals, mariculture operations, and remediation of pollutants, pesticides and insecticides used in agriculture. Also, marine pollution is an emerging problem in India (Glasby and Roonwal, 1995) and in this respect, without tampering with sea, investigations on mass microalgal cultures could be remedial.

We thank Bala T. Durvasula for help with photomontage of Plate 1.

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Tropical Cyclones

Recent global increase in multiple rapid intensification of tropical cyclones

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Rapid Intensification (RI) of Tropical Cyclones (TC) is defined as increase in the maximum sustained winds of at least 30 knots in a 24-hour period. Although TCs exhibit a range of intensification rates over the course of their lifetimes, in particular, the forecasting of RI, has proven to be a challenging task for TC forecasters. Forecasting can get even worse if TCs have experienced RI more than once in their lifetime (referred to as "multiple-RI TCs") . As the formation, intensification, and RI of TCs involve common environmental conditions, there is no particular set of processes or mechanisms that can be treated as special for RI that are different from the non-RI TCs. Thus, failure to forecast the RI of a TC can be attributed to our limited knowledge of TC intensification rates in response to varying environmental conditions. The intensity change of TC depends on the diabatic heating in the eye wall. The efficiency of warming in the eye wall is determined by the inertial stability inside the inner-core, which increases as TC intensifies. As the maximum heating corresponds to the maximum intensity change, the onset of RI in the TC life cycle is similarly determined by its initial intensity. When a TC's intensity is substantially lower than its maximum potential intensity (MPI), the likelihood of RI is high. As a result, the likelihood of TCs undergoing RI in their early stages, i.e.,Tropical Storm (TS) stages of life cycle is significant as compared to the post-TS stages (cat-1,2,3,4,5). The impact of climate change on RI characteristics, such as increased annual frequency and mean magnitude of RI, changes in geographical distribution, and seasonal fluctuations of RI, was reported. However, the distribution of RI events across the various stages of the TC life cycle, as well as recent changes, must be examined to improve our understanding of RI incidence within the

TC lifetime. The present study focuses on the variability in the evolution of intensification rates during the life cycle of TC, with a particular emphasis on the distribution of RI.

Historically, most RI TCs underwent RI during the initial phase (TS stage) of the TC life cycle. In our analysis of IBTrACS data for worldwide TCs developed between 1981 and 2020, it was discovered that the chance of TCs undergoing RI has increased in the Cat-1,2,3 stages during the last 20 years (Fig. 2). This shift in RI favorability to post-TS stages of TC increased the number of RI events within a TC life cycle, enhancing the frequency of multiple-RI TCs. Our analysis shows that the frequency of multiple-RI TCs has increased by 82.43% in 2000–2020 compared to that in 1981–2000, whereas the frequency of single RI TCs has increased by only 1.63% (Fig. 1). A significant increase in multiple-RI TCs frequency was observed across all ocean basins. As the oceans warm, the MPI rises, and the TC intensity, where it experiences a maximum intensification rate, also increases (Fig. 3). Thus, the post-TS stages of TC (cat-1,2,3) are becoming more suitable for RI initiation or progression, as they are still far enough from the theoretical upper limit of TC intensity. This process has significantly increased the frequency of multiple-RI TCs at a rate of 1.2 TCs/decade during 1981–2020 (Fig. 1). The lifetime maximum intensity (LMI) of multiple-RI TCs is approximately 20 knots higher than that of single-RI TCs. In a scenario of ongoing global warming, the rising frequency and magnitude of RI events within the TC life cycle in response to the rising MPI may further elevate LMI levels. This phenomenon has the potential to give rise to more severe and unpredictable storms in the future by amplifying the occurrence of multiple-RI events.

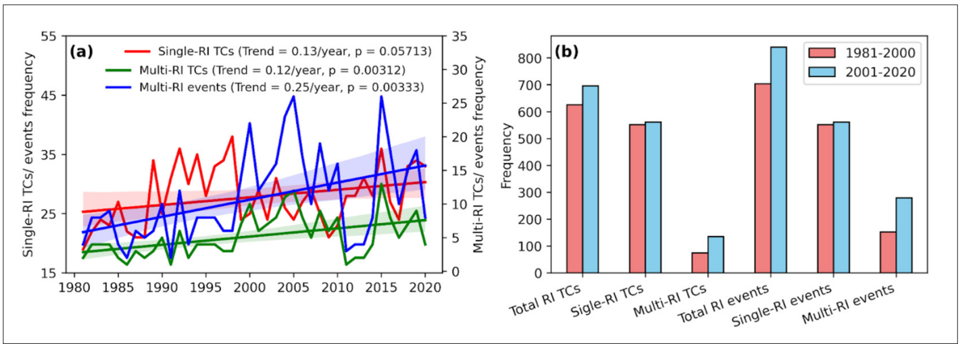

Fig. 1: (a) Time series and trend of annual single-RI TCs frequency (red) and multiple-RI TCs frequency (green) and multiple-RI events frequency (blue) during the period 1981–2020. (b) Frequency changes of total RI-TCs and total RI events, single-RI TCs, and events, multiple-RI TCs, and events between the periods 1981-2000 and 2001-2020.

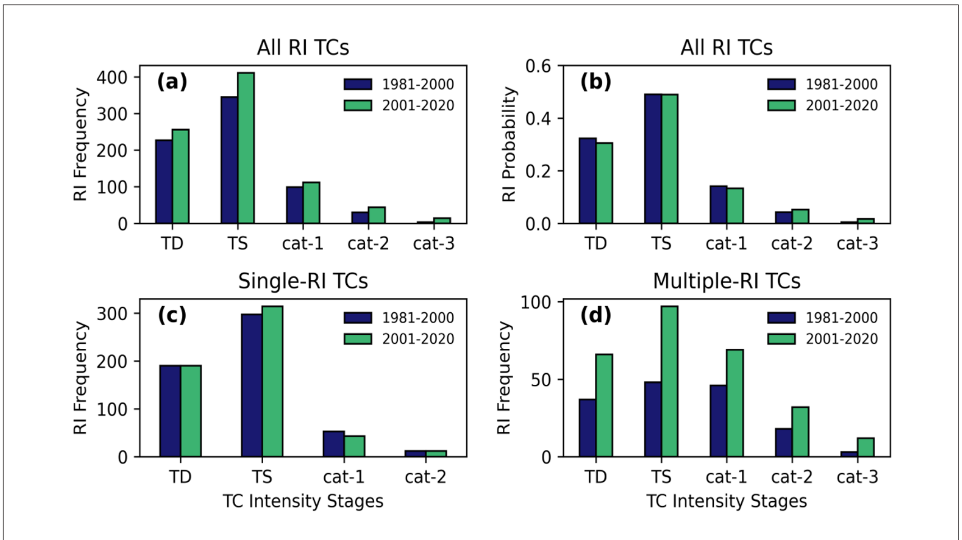

Fig. 2.: (a) Frequency distribution of RI events as a function of TC intensity categories for the period, 1981-2000 (dark blue); 2001-2020 (green) (b) Probability distribution of RI events among different stages of TC for the period, P1 (blue); P2 (green). Frequency distribution of RI for (c) single-RI TCs and (d) multiple-RI TCs.

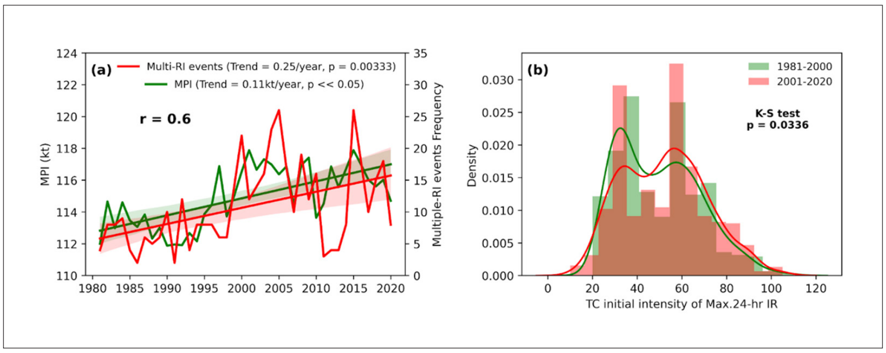

Fig. 3. (a) Time series of Maximum Potential Intensity (MPI) (shown in green color) calculated for global tropical oceans (30N—30S) for the period 1981–2020 using ERA5 data along with time series of multiple-RI events (red) (b) Distribution plots of initial TC intensity of maximum intensification rate for RI TCs for the periods 1981-2000 (green) and 2001-2020 (red).

Full-text reference:

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Informal Communication

The contribution of moisture to Indian summer monsoon rainfall during extreme event

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The Indian Ocean, a major component of the global ocean system, holds paramount significance in the Earth's climatic and oceanographic processes. Its complex dynamics, shaped by monsoonal winds, ocean currents, and thermohaline gradients, exert profound influences on regional and global climate patterns. Academic investigations into the Indian Ocean delve into understanding its intricate interactions, including the Indian Ocean Dipole and the impact of anthropogenic factors, contributing to a nuanced comprehension of the ocean's role in shaping environmental dynamics and variability.

During my research, an investigation into the contribution of monsoon rainfall across various regions of India was undertaken. The findings underscored the Indian Ocean as the primary contributor to monsoon rainfall in India, a determination substantiated by the implementation of the UTrack moisture model (Tuinenberg and Stall, 2020). This model facilitated the tracking of moisture trajectories, allowing for the discernment of contributions from distinctive

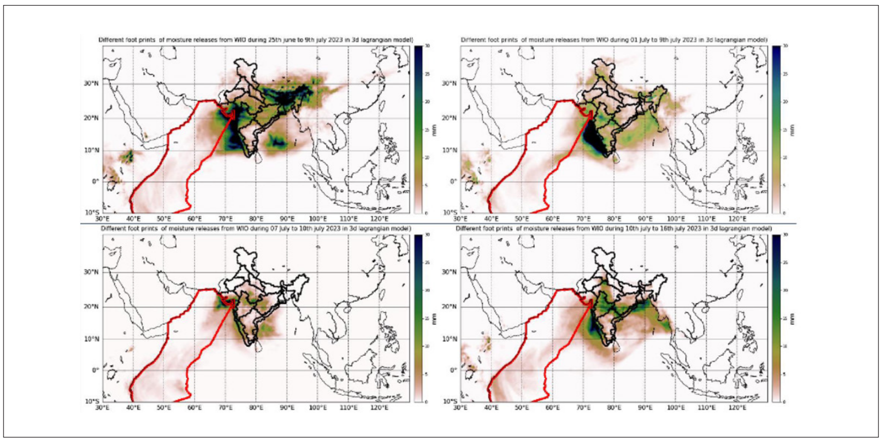

Fig. 1: The contribution of moisture to Indian summer monsoon rainfall during extreme event.

source regions such as the Bay of Bengal, Arabian Sea, Ganga Basin, Central and Southwestern Asia Land Region (CSWA), and the Western Indian Ocean (WIO).

The model was executed using data from June to September 2023 (JJAS) to enable the visual and mathematical observation of monthly contributions from the specified source regions. The Western Indian Ocean (Fig 1.) emerged as the principal contributor to monsoon rainfall. However, during extreme weather events, its contribution intensified, extending towards Northern India and the Ganga Basin. Additionally, the Central and Southwestern Asia Land Region (CSWA) played a significant role during northern extreme events.

Coastal regions experienced heightened rainfall, predominantly influenced by the Arabian Sea and WIO. Conversely, Northeast India demonstrated a noteworthy role of the Bay of Bengal and Ganga Basin during extreme events. These findings underscore the intricate interplay of moisture sources in shaping monsoonal patterns across India.

Further analysis is in progress on all the above facts related to my research. Fig. 1 for instance shows the contribution of moisture to Indian summer monsoon rainfall during extreme events. An extreme event is considered when the rainfall over grid points exceeds the 99.5th percentile of mean rainfall over 34 years (1990-2023). Four Extreme events during June and July have been presented in Fig. 1, which prove the fact that the Western Indian Ocean emerged as not only the principal contributor to monsoon rainfall but also the principal contributor to the extreme event as well.

UN Ocean Decade

IO-Con 2024 : Bridging Billions to Barcelona

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Proclaimed in 2017 by the United Nations General Assembly, the UN Decade of Ocean Science for Sustainable Development (2021-2030) ('the Ocean Decade') seeks to stimulate ocean science and knowledge generation to reverse the decline of the state of the ocean system and catalyse new opportunities for sustainable development of this massive ecosystem. The vision of the Ocean Decade is 'the science we need for the ocean we want'. The Ocean Decade provides a convening framework for scientists and stakeholders from diverse sectors to develop the scientific knowledge and the partnerships needed to accelerate and harness advances in ocean science to achieve a better understanding of the ocean system and deliver science-based solutions to achieve the 2030 Agenda. The UN General Assembly mandated UNESCO's Intergovernmental Oceanographic Commission (IOC) to coordinate the preparations and implementation of the Decade.

Decade Collaborative Centres (DCCs) and Decade Coordination Offices (DCOs) provide dedicated long-term support to coordinate Decade Actions at the regional (i.e. around major Ocean basins) or thematic (i.e. around Decade Challenges) levels. They support Decade Actions with capacity development, communications, tracking of progress and resource mobilisation, as well as catalysing new partnerships and initiatives as part of the Decade. DCCs and DCOs enhance collaboration, promote effective co-design and uptake of science, and optimize the use of resources among the diverse stakeholders that contribute to the Ocean Decade. The Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR) is to have a regional focus for the entire Indian Ocean Region.

To strengthen the momentum for ocean knowledge-based solutions, the Ocean Decade has launched a strategic ambition setting process to identify a common measure of success for each of the 10 Ocean Decade Challenges, on the road to 2030. It will take stock of current trends, gaps, and priority user needs and identify key targets and milestones to measure progress and enhance collective impact of the Decade. The Vision 2030 process will provide the answer to the question: What does success look like for these Challenges at the end of the Decade? Towards this, ten working groups pertaining to specific ocean decade challenges were formed globally, comprising subject experts. These working groups have formulated draft white papers which were made available publicly through DCU, for review and comments. The IO-Con 2024 provided a platform for presenting the white papers to wider audience/stakeholders and to seek feedback that could help in finalizing these white papers by the 2024 Ocean Decade Conference, in Barcelona, Spain during April 2024.

Photo: Glimpses of IO-Con 2024, 1-3 Feb 2024

The DCC-IOR is committed to address Ocean Decade Actions providing scientific coordination and planning, identifying collaboration opportunities, awareness raising and stakeholder engagement apart from interacting with the Decade Coordination Unit at IOC. The DCC-IOR, as its part of commitment, organized the 'Indian Ocean Regional Decade Conference (IO-Con) 2024: Bridging Billions to Barcelona', an Official Prelude to the Ocean Decade Conference-2024' with the following objectives. The conference is organized under the auspices of DCC-IOR, and its governing body served as the international steering committee of the conference. The second meeting of DCC-IOR GB was held as a side-event of the IO-Con 2024.

Objectives

1. To involve and engage stakeholders of the Indian Ocean Region in Ocean Decade activities.
2. To provide a platform for deliberating on the future priorities for the Ocean Decade Challenges that are emerging via the Vision 2030 process with focus to the IOR and feed regional inputs to the 2024 Ocean Decade Conference in Barcelona in April 2024.
3. To interact and network among the IOR stake holders including the national decade coordination committees of the Region.
4. To provide a platform to voice the concerns and expectations of the stakeholders from ECOPs, Academicians, Industries, Social Scientists, NGOs, and other ocean stakeholders.

The sessions (along with grouped ocean decade challenges) were organized so to reflect the organization of 2024 Ocean Decade Conference at Barcelona later, and to facilitate the key takeaways accordingly. Further, to address the national and regional dimensions a special session each on the NDCs and existing IOR-frameworks were also hosted. Each of these sessions started with a keynote. The keynote (except for the special sessions) focused on challenge specific white paper, usually by the Vision2030 working group co-chairs/member. This was followed by five invited talks by the subject-matter experts ensuring gender, geographical and generational diversity. Later, these speakers were joined by three more experts for the panel discussion. At parallel, audience was engaged with interactive online polls being run on the screen. The poll questions focused the ocean decade challenge in particular with an emphasis on the draft white paper as well.

During this policy conference more than three hundred delegates from India and abroad brainstormed on the ocean decade challenges through the dedicated sessions. A side-event for young researchers was organized collaboratively by IIOE2-ECSN and ECOPs programme. More details about the conference including session outlays and photo gallery, are made available at: https://incois.gov.in/dcc-ior/IORDC2024.jsp.

Training Report

IIOE-2 ECSN led 'DECCaD-IO' Training Events

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[2]NOAA Northwest Fisheries Science Center, USA.

The Early Career Scientists' Network (ECSN) established during the IIOE-2 has proposed to organize two trainings every year between 2023 and 2027 under the DECCaD-IO (Devising Early-Career Capacity Development in the Indian Ocean region), as major capacity building events during the ocean decade. The trainings that cover various marine science topics, will be designed in a strategic manner to cater to the EC requirements in the IO-region. A significant feature of this initiative will be that the ECs themselves will act as both students and faculty (along with senior tutors), nurturing thereby their metamorphosis from learners to teachers. The food security of millions

Photo: Glimpses of the ITCOocean training, Jan-Feb 2024

of coastal population spanning East Africa, West and East India, Bangladesh, and Myanmar depends on coastal and artisanal fisheries in the Indian Ocean region. In a pattern seen elsewhere too, climate change disproportionately affects vulnerable communities in the global south, and the impacts are exacerbated by a disparity in available resources. This disparity extends to the scientists as well from the Indian Ocean Rim countries, who face limited access to big data geoscience resources and cloud-based computing platforms- crucial areas of advancement in earth sciences and ocean climate change research in an era of high-data-volume Earth observations. Training on and access to these new cloud-based approaches have been overwhelmingly in the high income countries, leaving the next generation of ocean and marine scientists in the middle-to-low income countries in danger of falling behind, precisely at a time when big data geoscience is needed to help these countries adapt to ocean climate change.

To help bridge this gap, a pilot program was conducted at the International Training Centre for Operational Oceanography (ITCOocean) during September 11-22, 2023 using a 2i2c JupyterHub provisioned for cloud-based big data geospatial research in marine and ocean science. Seventy early career scientists from Indian Ocean Rim countries (East Africa, India, Bangladesh, and Myanmar) were trained in using big data geoscience tools during a two-week course and hack week on machine-learning for marine species distribution modelling, and given access to the hub to continue their research after the course. This eliminated the need for participants to install tools on their laptops, which often have diverse and older operating systems that are not necessarily supported by the latest software packages. A JupyterHub alleviates this issue, as it requires only a browser and modest internet connectivity. However, concerns remain about the practicality of cloud platforms in regions with intermittent internet connectivity, and whether the scientists will be able to continue to use cloud-platforms effectively when they return to their home institutions.

The ITCOocean (a UNESCO Category-II Centre) at INCOIS, Hyderabad, India also hosted its first ever training funded by ITEC (Indian Technical and Economic Cooperation) program of the Ministry of External Affairs (MEA), Govt. of India. The training titled 'Fishery Oceanography for the Ocean Decade (F.O.O.D.) – 2024' spanned three weeks during 18 Jan-7 Feb 2024. A total of 11 international participants from 7 countries of the Indo-Pacific region comprised the trainee pool. After initial rigorous fishery-oriented training, the participants were provided greater networking and collaborative opportunities with another (POGO funded) training initiated under the auspicious of ITCOocean. The ITCOocean also hosted a POGO-funded international training program 'Ocean Observations for Coastal Applications' during 29 Jan-7 Feb, 2024. The gender-balanced pool of 30 participants belonged to 11 countries. This was the first professional training ever for at least two young researchers from outside the host country. The training was coordinated by POGO-alumni Dr. Nimit Kumar with the support of regional POGO partners including Dr. Subrata Sarker (SUST, Bangladesh), also a POGO-CofE alumni and Coordinator of the NANO-DOAP project, Dr. Sachinandan Dutta (SQU, Oman), Dr. Aileen Tan (CEMACS, Malaysia), Dr. TVS Udaya Bhaskar (ITCOO coordinator), and Dr. Sourav Maity (VU-COOC, India). The training featured invited talk by Dr. Eric Raes who leads OceanOmics project of Minderoo Foundation, which is part of a POGO-led endorsed Ocean Decade action - OBON. The training was also associated with another endorsed Ocean Decade action DECCaD-IO, which is led by Nimit on behalf of IIOE-2's ECSN. As a part of this initiative, Ms. Nabanita Das and Ms. Shashowti Chowdhury Riya participated in co-designing the training and delivered a joint-talk. With the support extended by INCOIS, the trainees participated in the first ever in-person regional ocean decade conference IO-Con 2024, organized by DCC-IOR during 1-3 Feb 2024. The participation of the trainees was not limited to attendance but was also in the form of invited speakers and panellists. This provided a unique opportunity to onboarding the participants to the UN Ocean Decade as well as providing vital inputs to the Vision 2030 process, which leads to the global conference at Barcelona, Spain in April 2024. The trainees also participated in a side-event dedicated to ECOPs. Followed by theoretical classes and the conference, the trainees were taken to eastern port city of Visakhapatnam (Vizag), along with another batch of international trainees, providing not only a hands-on field campaign experience but also to wider international networking opportunities beyond the pool of this training. The field training was coordinated by another team of POGO-alumni comprising Dr. Aneesh Lotliker and Sajiba Baliarsingh, with the support from Mr. Narasimha Darapu and team of Andhra University's CSBOB (Centre for Studies on Bay of Bengal) led by Profs. P. Rajendra Prasad and P. Rama Rao.

News Updates

New interdisciplinary edited book on the Indian Ocean to be published in spring 2024

The Indian Ocean and Its Role in the Global Climate System,
Eds. Caroline C. Ummenhofer, Raleigh R. Hood, Elsevier, 2024
ISBN: Paperback-9780128226988, eBook-9780128232866,
https://shop.elsevier.com/books/the-indian-ocean-and-its-role-in-the-global-climate-system/ummenhofer/978-0-12-822698-8

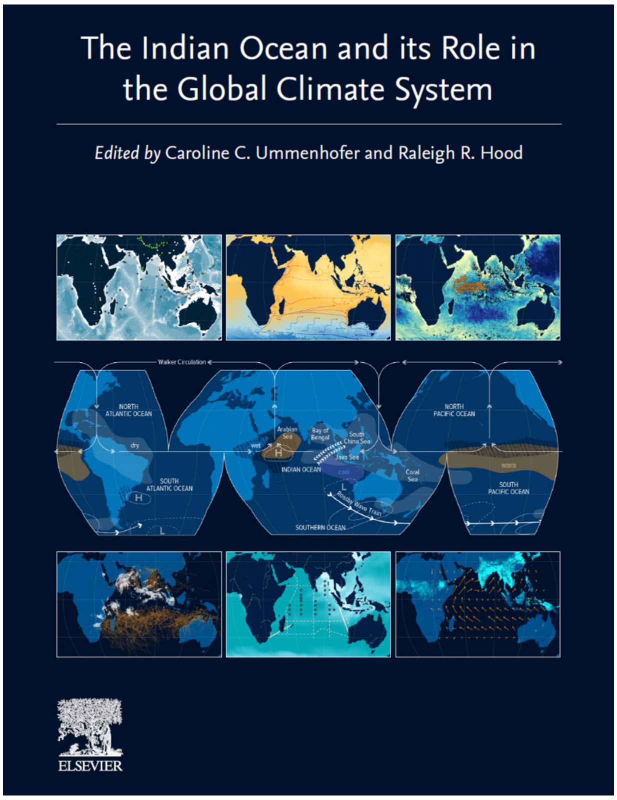


Fig. 1: Image of front cover for the edited interdisciplinary book on the Indian Ocean, The Indian Ocean and Its Role in the Global Climate System, to be published by Elsevier in spring 2024.

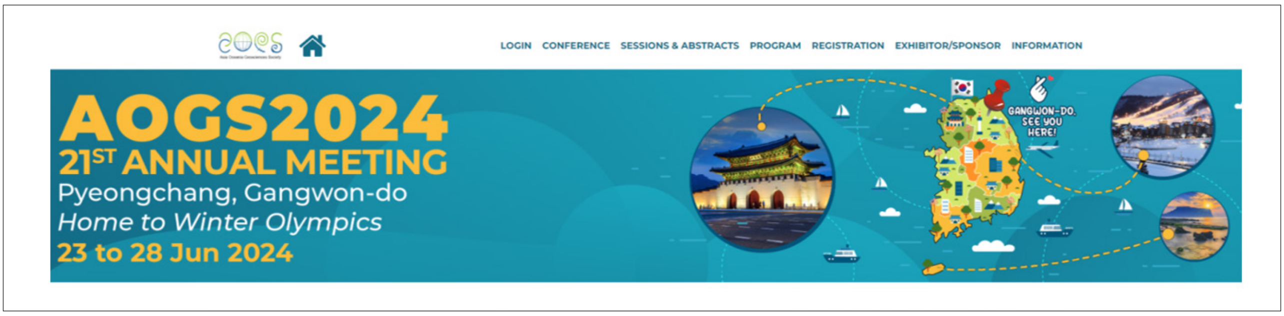
Given the unique characteristics of the Indian Ocean and the fact that it has historically been understudied, the understanding of the Indian Ocean as a holistic system is still limited. A new book to be published by Elsevier in 2024 provides a rare interdisciplinary synthesis of recent advances in the knowledge and understanding of the physical climate system of the Indian Ocean (geology, hydrology, atmosphere, oceanography), interlinked with interactions with its biogeochemistry and ecology, and impacts on human and natural systems in surrounding countries. The monsoon systems, Indian Ocean circulation, and connections with other ocean basins and climatic phenomena are detailed from seasonal, interannual to multidecadal timescales. Recent trends and future projections of the Indian Ocean, including warming, extreme events – both in the physical as well as biogeochemical realm – such as marine heatwaves, climate and weather extremes, ocean acidification, and deoxygenation are examined. The book also identifies and highlights recent new understanding and technologies to provide stakeholders with relevant knowledge for more informed decision-making, as well as highlighting knowledge gaps to encourage students, practitioners, and researchers to help overcome these.

With a total of 20 peer-reviewed chapters, and more than 175 figures, 3,000 references, 100 educational resources and links directing readers to more in-depth information, and 100 glossary entries of key concepts, the book delivers a comprehensive overview of our current understanding of the Indian Ocean from an interdisciplinary perspective. Contributions by a total of 92 authors from around the world with expertise across a wide range of fields (e.g., atmospheric and climate science, biogeochemistry, ecology, environmental science, fisheries, geology, history, meteorology, microbial ecology, numerical modeling, all fields of oceanography, paleoclimate, remote sensing, statistics, and weather forecasting, among others) underpin the content of this textbook. Furthermore, all chapters were peer-reviewed by at least two experts in the field: the constructive and valuable feedback by a total of 39 reviewers ensured that the material in the individual chapters and the book as a whole provides a comprehensive, interconnected, and up-to-date review of Indian Ocean science. The time and efforts of all members of the Indian Ocean research community that have helped with the completion of this book are gratefully acknowledged.

Caroline C. Ummenhofer, Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA, USA, cummenhofer@whoi.edu

Raleigh R. Hood, Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, MD, USA, rhood@umces.edu

21st Annual Meeting of the Asia Oceania Geoscience Society (AOGS2024)



Asia Oceanis Geosciences Society (AOGS) was established in 2003 to promote geosciences and its application for the benefit of humanity specifically in Asia Oceania region is particularly vulnerable to natural hazards, accounting for almost 80% human lives lost globally. AOGS is deeply involved in addressing hazard related issues through improving our understanding of the genesis of hazards through scientific, social and technical approaches. AOGS holds annual consumptions providing a unique opportunity of exchanging scientific knowledge and discussion to address important geo-scientific issues among academia, research instituion and public. Recognizing the need of global collaboration AOGS has developed good co-operation with other internation geo-science societies and unions such as the European Geosciences Union [EGU], American Geophysical Union (AGU) International Union of Geodesy and Geophysics (IUGG), Japan Geo-science [JpG], and Science Council of Asia [SCA].

The 21st Annual Meeting of the Asia Oceania Geoscience Society (AOGS2024) will be held in Pyeongchang, Gangwon-do (Home of Winter Olympics), South Korea during 23 to 28 June 2024. More details: https://www.asiaoceania.org/aogs2024/public.asp?page=home.asp

Session(s)

OS - Ocean Sciences (Primary), AS - Atmospheric Sciences

Session OS06: Physics, Biogeochemistry, and Climate Dynamic of the Indian Ocean

Conveners

* **Prof SungHyun Nam** (Seoul National University)

Dr Nicolino (Nick) D'Adamo (Adjunct Research Fellow, Oceans Institute of the University of Western Australia)

Dr Dong-Jin Kang (Korea Institute Of Ocean Science And Technology)

Dr Yukio Masumoto (The University of Tokyo)

Description

Recent increases in extreme events such as flooding, droughts, heatwaves, and tropical cyclones have a large impact on the population living in the Asia and Oceania countries. Increasing evidence on the roles of Indian Ocean in impacting climate extremes, climate variability, and climate change via changes in energy, hydrological and biogeochemical cycles has been reported. The Indian Ocean is of particular interest, for example, as influenced by the seasonally reversing monsoon forcing and upwelling centers in the Indian Ocean found in the off-equatorial regions unlike in the easterly wind-forced Pacific and Atlantic Oceans. The northern region is dominated by the monsoons whereas the seasonal reversal is less pronounced in the southern region. This session invites contribution of physics, biogeochemistry, and climate dynamics of Indian Ocean based on in-situ and remotely-sensed observations, models, theories, and paleo proxies that reveal processes, variability, and projected changes within the Indian Ocean. This includes, but is not limited to 1) Indian Ocean variability such as Indian Ocean Basin Mode, Indian Ocean Dipole Mode, Madden-Jullian Oscillations, 2) Upwelling in the Indian Ocean such as open-ocean upwellings or thermocline ridge/dome (e.g., Seychelles-Chagos Thermocline Ridge) and coastal upwellings at both western and eastern sides, 3) Processes underlying basin-scale or regional circulation, 4) Ocean-atmosphere interaction processes (heat, freshwater, momentum, carbon, etc.), 5) Biogeochemistry of the Indian Ocean water masses, 6) Links between ocean sciences and socio-economic requirements in the Indian Ocean, and 7) Interactions and exchanges between the Indian Ocean and other basins. Abstracts on related activities, such as capacity building, education, outreach, project development in the Indian Ocean, contributing to the UN Decade of Ocean Science for Sustainable Development and to the Second International Indian Ocean Expedition are also welcome.

Session AS04: The Asian Monsoon and Climate Change

Conveners

Dr Ramesh Kripalani (India)

Prof Kyung-Ja Ha (South Korea)

Prof Jun Matsumoto (Japan)

Prof Jai-Ho Oh (South Korea)

Prof Renguang Wu (China)

Description

The prime objective is to bring scientists together to bridge the gap in our knowledge and understanding the major issues and challenges of the Asian Monsoon.

Link for Session AS04 details: https://meetmatt-svr.net/Sp/Details?id=1139

Link for Abstract Submission: https://meetmatt-svr.net/Abstracts/SubmitNew?id=6

International Maritime Conference on Marine Conservation and Sustainability:

Celebrating 50 Years of MARPOL

Cochin University Maritime Club
School of Legal Studies, Cochin University of Science and Technology, Kerala, India

The Cochin University Maritime Club, School of Legal Studies at the Cochin University of Science and Technology, in collaboration with the ICAR – Central Institute of Fisheries Technology, and the Society of Fisheries Technologists (India), Kochi, hosted a two-day International Maritime Conference on October 19 and 20, 2023 at the School of Legal Studies campus. The theme of the International Maritime Conference was Marine Conservation and Sustainability: Celebrating 50 Years of MARPOL, which was in alignment with the theme of World Maritime Day 2023, celebrated by the International Maritime Organisation (IMO).

The inaugural ceremony commenced with a Welcome Address by Dr Harigovind P C, the Director of the School of Legal Studies, CUSAT. Dr P G Sankaran, the Vice Chancellor of CUSAT, graced the occasion as the chief guest, inaugurating the conference and delivering the Inaugural Address. Dr. George Ninan, Director of ICAR-CIFT gave the Presidential Address, while Advocate Joy Thattil Ittoop, Managing Partner of Callidus Legal delivered the keynote address, followed by a Special address by Dr. Luther M. Rangreji, Joint Secretary to the Government of India in the Ministry of External Affairs, Legal & Treaties Division.

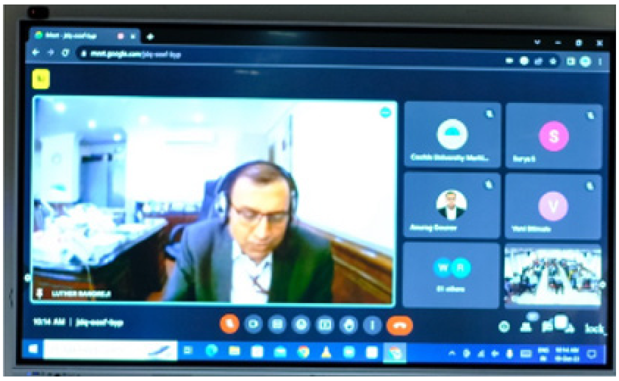
In the inaugural ceremony, a book titled 'Marine Conservation & Sustainability: Celebrating 50 Years of MARPOL' was released by Dr P G Sankaran, Vice-Chancellor, CUSAT by handing it over to Dr George Ninan, Director, ICAR-CIFT. The book is an edited compilation of 33 papers selected for publication from among over 100 submissions received. Closing the ceremony on a note of gratitude, Dr Binu Mole K, Assistant Professor at the School of Legal Studies, acknowledged the contributions of the esteemed speakers and participants.

The introductory session of the conference, chaired by Dr Seema P S, Associate Professor, School of Legal Studies, CUSAT, underscored the significance of addressing marine pollution in the current context. In the session, Dr Wassem Ahmad Bhat, Assistant Professor of Law at the School of Maritime Law, Policy, and Administration, Gujarat Maritime University, provided insights into the history and development of the MARPOL Convention. He highlighted that major oil spills were instrumental in its formation and noted the constant challenge of aligning ecological interests with economic considerations in conventions. Mr Aditya Variath, Assistant Professor of Law and Coordinator at the Centre for Research in Air and Space Laws, NLU, Mumbai, delved into the practical aspects of a circular marine economy, emphasizing its potential to reduce emissions. Adv Syam Kumar V M, a prominent practitioner in the High Court of Kerala, addressed the enforcement of MARPOL through port state control. He discussed the challenges, particularly financial corruption within port control authorities, impacting the consistent application of MARPOL provisions.

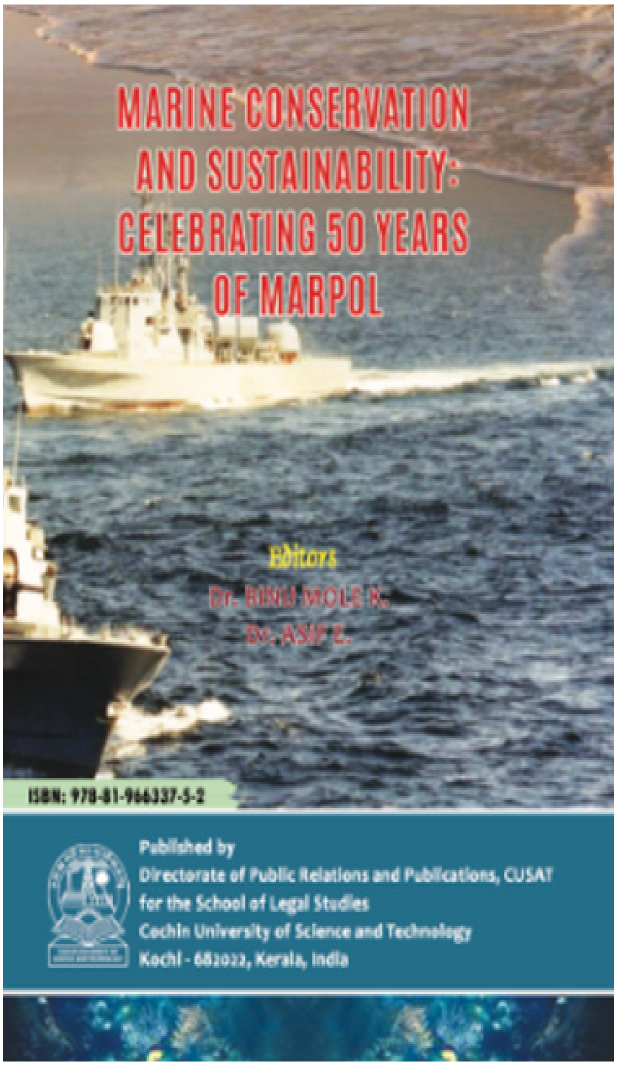
Dr Vani Kesari A, Principal Coordinator, ICREP, CUSAT and Associate Professor, School of Legal Studies, CUSAT, presided over the second technical session. Dr Rabia M'Rabet Temsamani, Lecturer at the International University

Book Release

Participants and Audience



Dr Luther M Rangreji



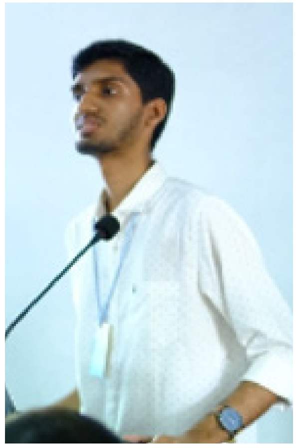
Book: Marine Conservation and Sustainability : Celebrating 50 Years of MARPOL

of Andalusia, Spain, and Post-Doctoral Fellow at the University of Jaen, Spain, addressed the audience on "Marine Renewable Energies and the Protection of the Marine Environment in the Light of International Law." She emphasized the formidable challenge of achieving sustainability in the maritime industry, advocating for improved shipbuilding practices and the utilization of alternative fuel sources such as geothermal, tidal, and ocean power. Additionally,

Dr Harigovind P C

Adv. Joy Thattil

Dr Binu Mole K
Faculty Coordinator



Mr Rekhil S
Student Coordinator

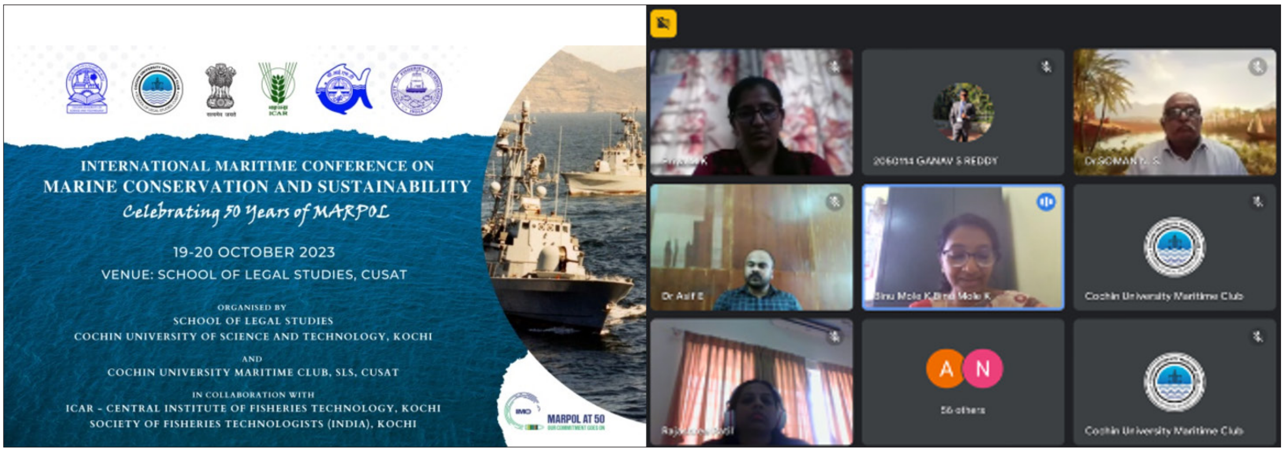
Dr. Gifty Oommen, Associate Professor, Government Law College, Ernakulam, presented an overview of the development and progress made in the regulation of oil spillage over the past five decades. The discussion centred on the impact of shipwrecks on marine life and emphasized the necessity of collaboration in order to guarantee the effectiveness of MARPOL. Dr Jacob Joseph, Director of the Centre for Law & Agriculture and faculty member at NUALS, Kochi, elaborated on the intentions and ambitions of the BBNJ Agreement, as well as its conservation objectives for marine biodiversity. Dr. Binu Mole K., Assistant Professor, School of Legal Studies, CUSAT, led a session titled "Challenges of Flag State Initiatives for Mitigating Ship-Induced Pollution." During the presentation, she emphasized the need for flag states to enforce international conventions such as MARPOL and addressed the absence of sanctions for noncompliance with jurisdiction.

The third technical session was chaired by Dr Satheesh Babu P K, Head of the Department, Department of Ship Technology, CUSAT. In the session, Dr V R Madhu, Principal Scientist at ICAR-CIFT, Kochi, delivered a lecture on "Fishing Technology Innovations to Foster Marine Conservation" and discussed the use of different fishing nets to reduce bycatch. Dr Muhamed Ashraf P, Principal Scientist at ICAR-CIFT, Kochi, discussed the history and current applications of nanotechnology in the marine industry, including fuel efficiency and corrosion prevention. Dr N Manjulekshmi, Scientist at ICAR-CIFT, Kochi, deliberated on "Marine Litter and Its Management.", addressing the surge in plastic production since 1950 and its impact on marine ecosystems, with a focus on fishing-related plastics and its management. Mr Paras Nath Jha, Scientist at ICAR-CIFT, Kochi, talked about "Carbon Emissions and Credit in Marine Fisheries" and explained the concept of carbon credit and suggested methods to reduce carbon emissions in marine fisheries.

The fourth technical session was chaired by Mrs Jean Vinitha Peter, Assistant Professor, School of Legal Studies, CUSAT. In the session, Dr Sony Vijayan, Professor at the School of Law, Manipal University, Jaipur, discussed "Decarbonisation of Shipping: International Law and India's Response", exploring international laws regulating emissions and India's compliance with EEDI and MEPC regulations. Mr Joy Devassy, Construction Manager at Royal Haskoning DHV, Philippines, talked about the "Environmental Impact of Marine Construction" and delved into the environmental impacts of structures like breakwaters, bridges, and ports, emphasizing the importance of scientific study and planning in reducing pollution.

The fifth technical session was on the second day of the conference. Dr Nemat Sheereen S, Assistant Professor, School of Legal Studies, CUSAT, chaired it. In the session, Dr Shiju M V, Professor, School of Law, Sai University, Tamil Nadu, deliberated on "Indian Coastal Aquaculture Law in the Context of Blue Economy", emphasizing the pivotal role of the blue economy in national development and the need for appropriate laws to enhance the country's economic growth, particularly benefiting fishing communities. Adv Anjana Gopan, Associate Partner at Callidus Corporate and Maritime Consultancy (CCMC), Dubai, discussed "Milestone of Marine Environmental Protection: A Relook at MARPOL", revisiting MARPOL as a legal instrument, examining its impact on marine pollution. Dr Pallab Das, Associate Professor, School of Law, Centurion University, delivered a lecture on "MARPOL: Understanding the Idea Behind the Convention", exploring the origins and aspirations behind MARPOL, shedding light on the foundational principles of the convention.

Beyond the rich discussions, the conference served as a melting pot for students and professionals, with over 100 research papers being presented at the conference, spanning over nine different sessions. The topics covered were as expansive and varied as the ocean itself, ranging from the historical origins of the MARPOL Convention to discussions on circular economies in maritime decarbonization, enforcing MARPOL through Port State Control, marine renewable energies, 50 years' progress in oil spillage regulations, conservation of marine biodiversity, and innovative pollution control strategies.



During the valedictory session that concluded the conference, Dr. Asif E., Assistant professor at the School of Legal Studies, CUSAT, extended a warm greeting to the attendees. A valedictory address was delivered during the session by Dr. N. S. Soman, Professor, School of Law, Christ University, Pune. A comprehensive report presentation was delivered by Mr. Rekhil S, the Student Coordinator. The conference concluded with a vote of thanks presented by the Student Coordinator, Ms Mariya P S.

Call for Contributions

Informal articles are invited for the next issue. Contributions referring Indian Ocean studies, cruises, conferences, workshops, tributes to other oceanographers etc. are welcome. Articles may be up to 1500 words in length (MS-Word) accompanied by suitable figures, photos (separate .jpeg files).

Deadline: **05th May 2024**

Send your contributions as usual to to **iioe-2@incois.gov.in**

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